LONDON-WEST MIDLANDS ENVIRONMENTAL STATEMENT

Volume 5 | Technical Appendices

CFA23 | Balsall Common and Hampton-in-Arden

River Blythe catchment preliminary flow calculations technical report (WR-004-016)

Water resources

November 2013

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November 2013

Department for Transport

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Appendix WR-004-016

Environmental topic:	Water resources and flood risk assessment	WR
Appendix name:	Hydrology report	004
	River Blythe catchment preliminary flow calculations technical report	016

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1 Introduction

1.1 Structure of the water resources and flood risk assessment appendices

1.1.1 The water resources and flood risk assessment appendices comprise a number of parts. The first of these is a route-wide appendix (Volume 5: Appendix WR-001-000).

1.1.2 A number of specific appendices for each community forum area are also provided. For the Balsall Common and Hampton-in-Arden (CFA23) and Birmingham Interchange and Chelmsley Wood area (CFA24) these are:

- water resources assessments (Volume 5: Appendix WR-002-023 and WR-002-024);
- flood risk assessments (Volume 5: Appendix WR-003-023 and WR-003-024)
- a hydrology report for the River Blythe and associated tributaries (this appendix);
- a hydraulic modelling report for the River Blythe and Bayleys Brook at Balsall Common viaduct (Volume 5: Appendix WR-004-017); and
- a hydraulic modelling report for the for Bayleys Brook (at Marsh Farm and Lavender Hall Lane), the River Blythe Bypass, Shadow Brook and Hollywell Brook (Volume 5: Appendix WR-004-018).

1.1.3 Maps referred to throughout the water resources and flood risk assessment appendices are contained in the Volume 5 water resources map book.

1.2 Scope of this assessment

1.2.1 The following process has been followed to derive preliminary flows:

- catchment identification using Flood Estimation Handbook (FEH)[1] CD Rom;
- comparison and check of catchment extent to independent mapping sources;
- extraction of catchment descriptors; and
- derive peak flows and hydrographs for each calculation point for a range of return period floods using the ReFH spreadsheet and the where appropriate .

1.3 Location

1.3.1 This report focuses on CFA23 Balsall Common and Hampton-in-Arden and Birmingham Interchange and Chelmsley Wood area (CFA24). The areas of consideration are shown in Figure 1: Balsall Common and Hampton-in-Arden (CFA23) and Figure 2.

[1] Centre for Ecology and Hydrology, 1999, Flood Estimation Handbook (FEH)

Figure 1: Balsall Common and Hampton-in-Arden (CFA23)

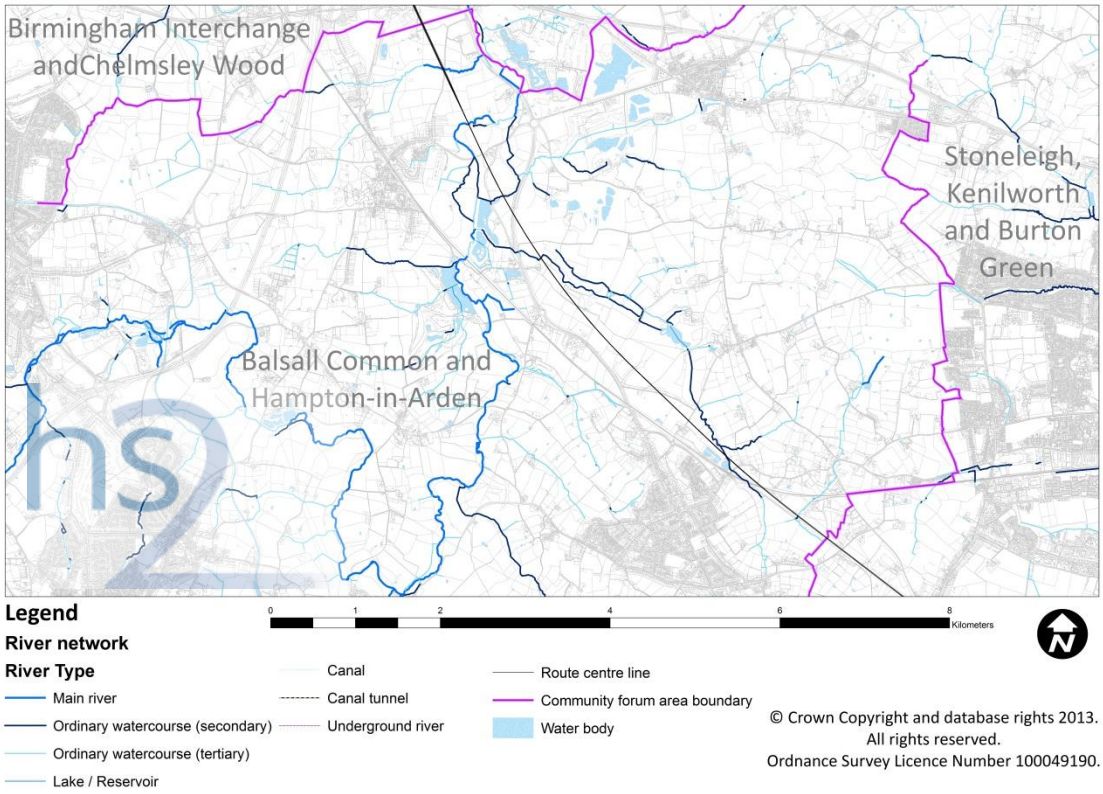
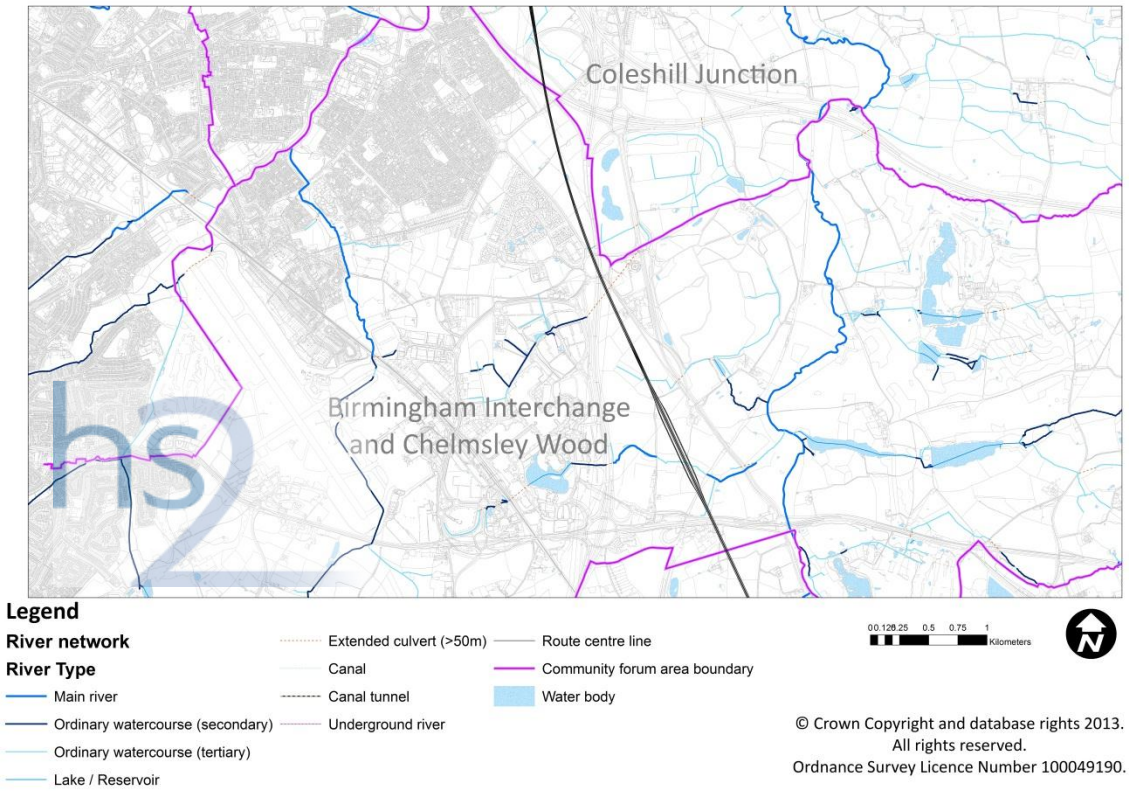


Figure 2: Birmingham Interchange and Chelmsley Wood (CFA24)



2 Overview

2.1.1 In order to assess the impact of the Proposed Scheme and associated engineering works on the River Blythe catchment, in terms of flood risk, there is a need to estimate flow for a range of extreme flow events.

2.1.2 It is appropriate to generate preliminary flow estimates for the River Blythe catchment using the Revitalised Rainfall Runoff method (ReFH).

2.1.3 The catchment contributing to each flow calculation point has initially been based on the catchment outline shown on the Flood Estimation Handbook[2] CD Rom (FEH CD Rom). However, these catchments have been cross referenced with the contours shown on Ordnance Survey mapping sources.

2.1.4 Where significant differences in catchment outline have been identified the catchment has been investigated further and in some cases the catchment outline used has been adjusted. However, the adjustment process has been kept to a minimum. The intention of this process has been to obtain an understanding of the magnitude of flow using ReFH methodology rather than undertake a detailed hydrological study which would involve the application of multiple flow calculation methods and calibration using observed data. However, in some key locations additional analysis has been undertaken in the form of the FEH statistical method.

2.1.5 The following annual exceedence probability (AEP) flows have been calculated for each flow calculation point:

- QMED;
- 20% AEP;
- 10% AEP;
- 5% AEP;
- 2% AEP;
- 1.33% AEP;
- 1% AEP;
- 1% AEP plus additional allowances for climate change; and
- 0.1% AEP.

2.1.6 Allowances for climate change include an increase of 20% and 30% on the 1% AEP event.

[2] Centre for Ecology and Hydrology, 1999, *Flood Estimation Handbook (FEH)*

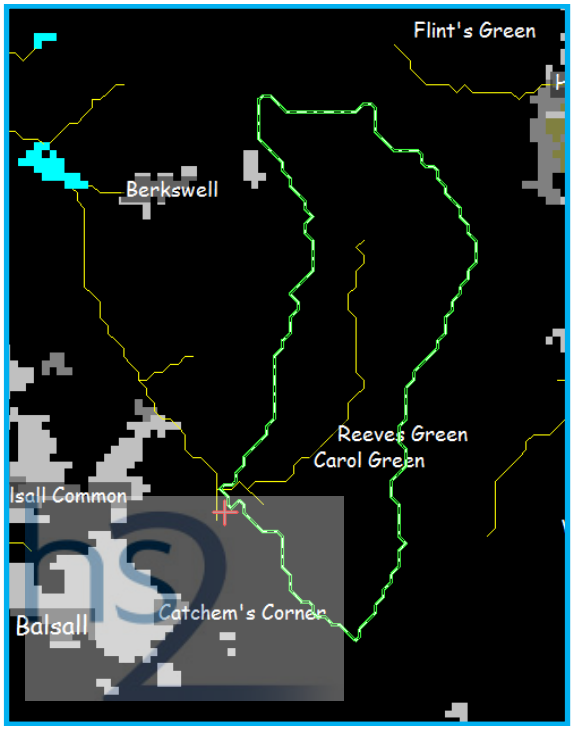
3 Flow estimation

3.1 Flow estimation point 1 - chainage 148+200 (tributary of Bayleys Brook at Meriden Greenway)

3.1.1 Flow estimation point 1 is for a tributary of the Bayleys Brook, which crosses the Proposed Scheme at chainage 148+280.

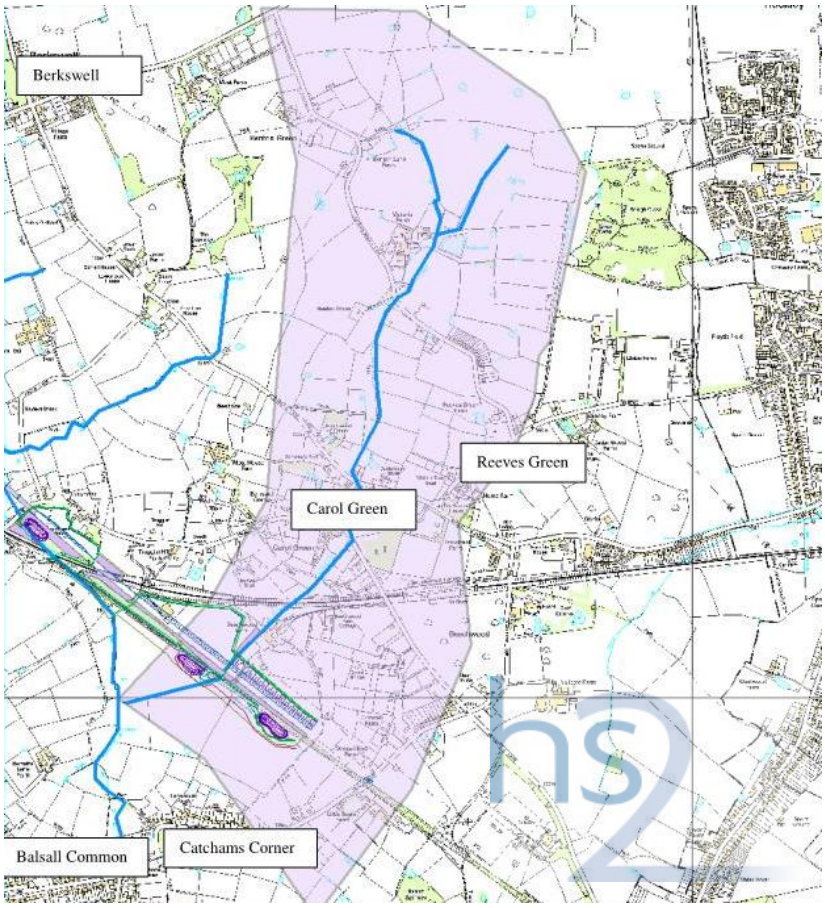
3.1.2 The contributing catchment for this watercourse has been identified on the FEH CD Rom. This is shown in Figure 3.

Figure 3: Catchment outline shown on FEH CD Rom



3.1.3 The catchment indicated on the FEH CD Rom can be confirmed as being representative of the actual contributing catchment at this location using Ordnance Survey mapping sources. This is shown in Figure 4.

Figure 4: Catchment outline from Ordnance Survey mapping sources



3.1.4 Therefore, the FEH CD Rom catchment area has been applied at this location with no modifications.

3.1.5 The catchment descriptors taken forward to the calculation process are from the FEH CD Rom with no adjustments applied. These are shown in Table 1.

Table 1: Catchment descriptors from FEH CD Rom

Catchment descriptors	Value
Area, km^2	2.98
SAAR, mm	693
BFIHOST	0.422
SPRHOST	40.59
URBEXT	0
PROPWET	0.3
DPSBAR, m/km	19.7
DPLBAR, km	1.85
c	-0.02544
d1	0.37127

Catchment descriptors	Value
d2	0.34472
d3	0.23496
e	0.29797
f	2.41704

3.1.6 A storm duration of 6.2 hours has been calculated based on the method outlined in the FEH Supplementary Report Number 1. To allow the model to run a time step of 1.24 hours has been selected.

3.1.7 The flows generated by the ReFH spreadsheet are shown in Table 2.

Table 2: Flow calculation results using ReFH

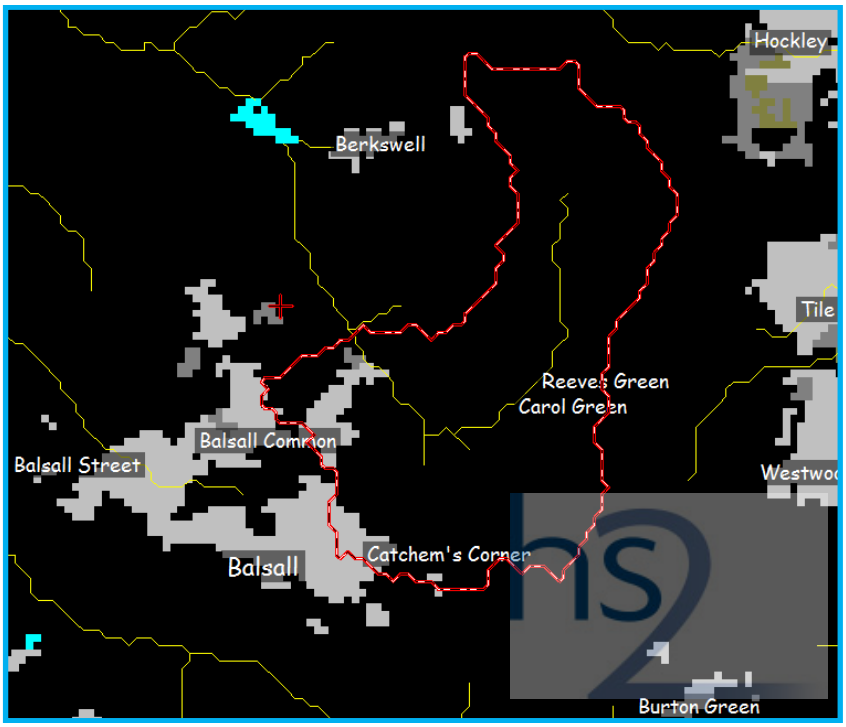
AEP	Flow (m^3/s)
QMED	0.9
20%	1.18
10%	1.40
5%	1.63
2%	1.98
1.33%	2.16
1%	2.30
1%+20%	2.76
1%+30%	2.99
0.1%	4.10

3.2 Flow estimation point 2 – chainage 149+400 (Bayleys Brook at Balsall Common viaduct)

3.2.1 Flow estimation point 2 is for a location where the Proposed Scheme passes over Bayleys Brook in the vicinity of Berkswell station. The viaduct will cross the river at this location is referred to on the scheme drawings as Balsall Common viaduct. Flow has been estimated up to a point a significant distance downstream of the viaduct to allow for uncertainty at this stage of the flow calculation process and includes a significant tributary of the Bayleys Brook that flows in from the east.

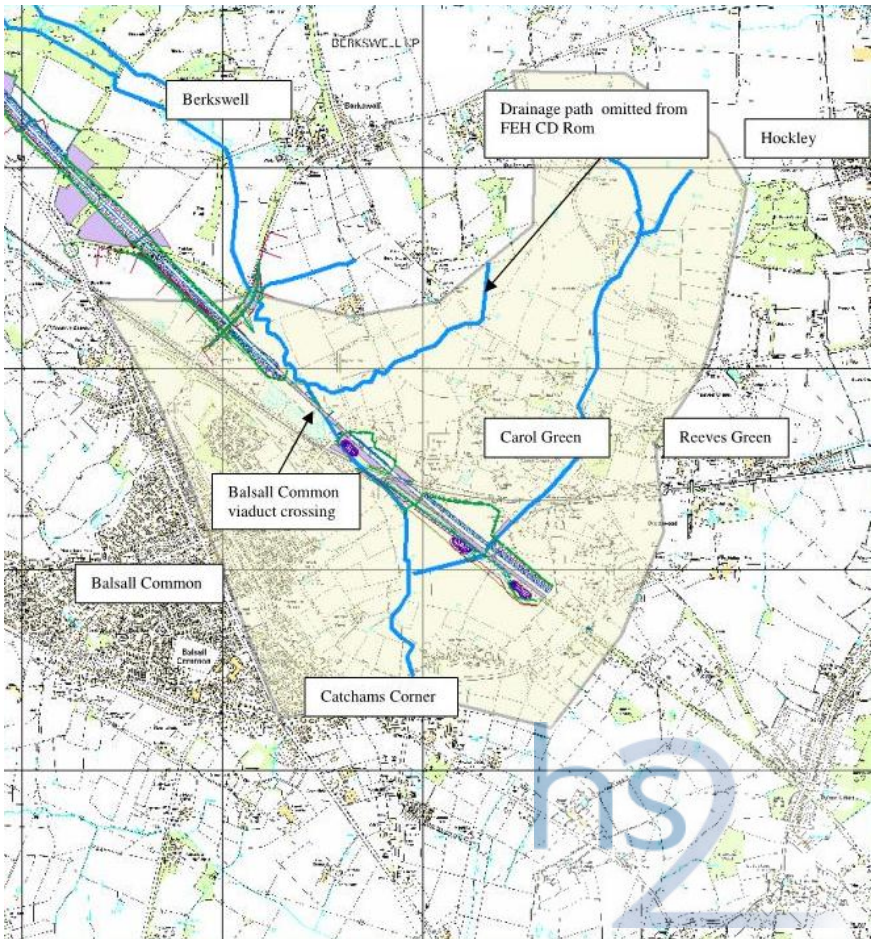
3.2.2 The contributing catchment for this watercourse identified on the FEH CD Rom is shown in Figure 5.

Figure 5: Catchment outline shown on FEH CD Rom



3.2.3 At this location the catchment extents identified by the FEH CD Rom do not completely agree with Ordnance Survey mapping sources. The catchment outline identified using the FEH CD Rom omits the watercourse from the east and indicates that it flows into the Bayleys Brook further to the north. Therefore, the catchment area indicated by the FEH CD Rom underestimates the size of the catchment at this point by 0.86km^2. The catchment as indicated by Ordnance Survey mapping sources is shown in Figure 6: Catchment outline from Ordnance Survey mapping sources this includes the watercourse omitted by the FEH CD Rom.

Figure 6: Catchment outline from Ordnance Survey mapping sources



3.2.4 The catchment descriptors taken forward to the calculation process from the FEH CD Rom, including the adjusted catchment area are shown in Table 3.

Table 3: Catchment Descriptors from FEH CD Rom

Catchment descriptors	Value
Area	5.66
SAAR	695
BFIHOST	0.437
SPRHOST	40.83
URBEXT	0.0293
PROPWET	0.3
DPSBAR	21.4
DPLBAR	2.2
c	-0.02553
d1	0.3693
d2	0.35105
d3	0.23608

Catchment descriptors	Value
e	0.29787
f	2.41452

3.2.5 A storm duration of 6 hours has been calculated based on the method outlined in the FEH Supplementary Report Number 1. To allow the model to run a time step of 1.2 hours has been selected.

3.2.6 The flows generated by the ReFH spreadsheet are shown in Table 4.

Table 4: Flow calculation results using ReFH

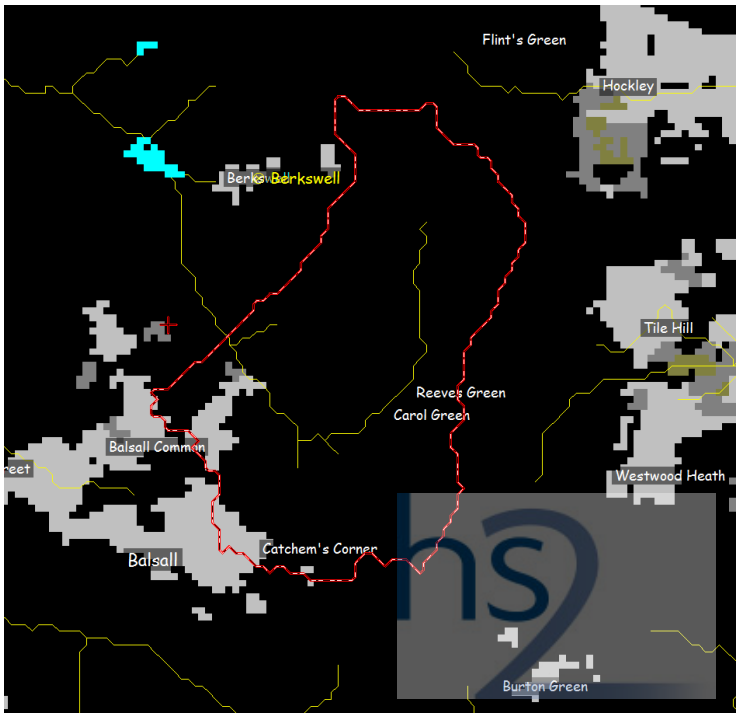
AEP	Flow (m^3/s)
QMED	1.64
20%	2.16
10%	2.56
5%	2.98
2%	3.62
1.33%	3.95
1%	4.20
1%+20%	5.04
1%+30%	5.46
0.1%	7.46

3.3 Flow estimation point 3 – chainage 149+900 (Bayleys Brook at Lavender Hall Lane)

3.3.1 Approximately 670m downstream of Balsall Common viaduct Bayleys Brook passes underneath Lavender Hall Lane. This road is being diverted as part of the Proposed Scheme and as a result a new crossing is required for the watercourse. Therefore, a flow estimate is required to account for the water in the Bayleys Brook. The flow estimate used for determining the amount of water in the Bayleys Brook at Balsall Common viaduct does not account for a tributary watercourse that flows from the east. Consequently this additional inflow has been taken into account at this location.

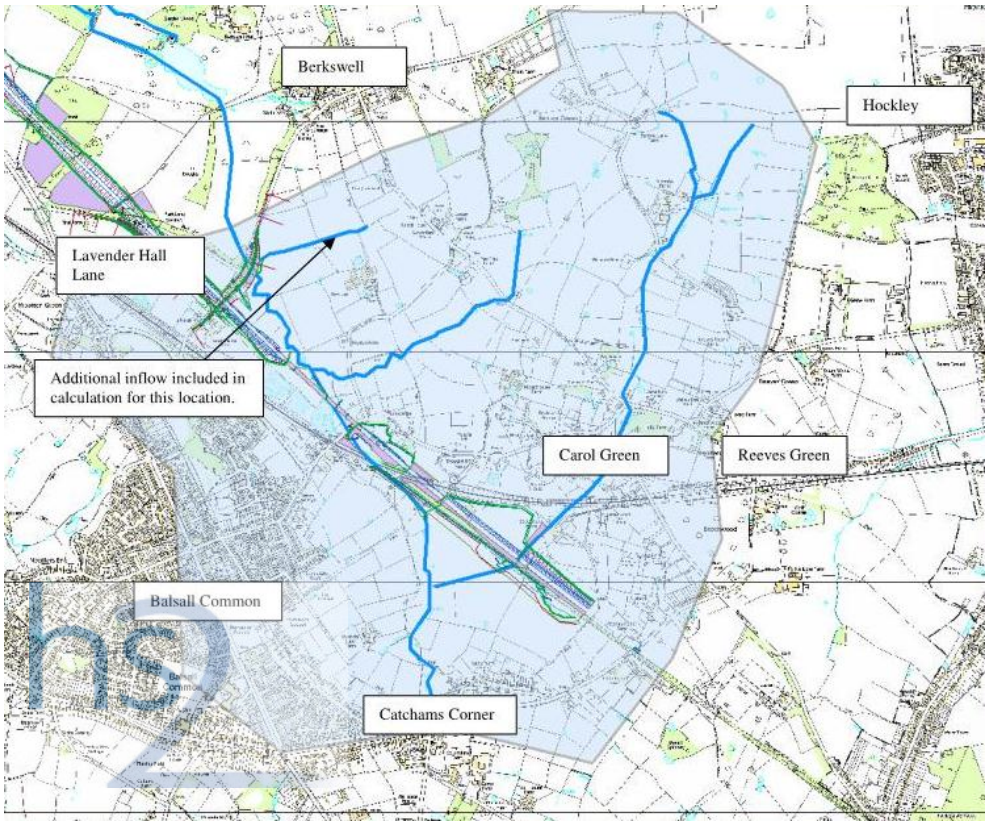
3.3.2 The contributing catchment identified on the FEH CD Rom is shown in Figure 7.

Figure 7: Catchment outline shown on FEH CD Rom



3.3.3 As described in Section 3.2, the FEH CD Rom does not represent the catchment of Bayleys Brook in a completely accurate manner in this location. It misrepresents the inflows from the east and so underestimates the catchment area. This has been addressed and the catchment outline identified using Ordnance Survey map sources is shown in Figure 8.

Figure 8: Catchment outline from Ordnance Survey mapping sources



3.3.4 The catchment descriptors taken forward to the calculation process from the FEH CD Rom, including the adjusted catchment area are shown in Table 5.

Table 5: Catchment descriptors from FEH CD Rom

Catchment Descriptors	Value
Area, km^2	6.53
SAAR, mm	696
BFIHOST	0.456
SPRHOST	40.71
URBEXT	0.0259
PROPWET	0.3
DPSBAR, m/km	23.8
DPLBAR, km	2.53
c	-0.026
d1	0.367
d2	0.356
d3	0.242
e	0.3
f	2.402

3.3.5 A storm duration of 6.5 hours has been calculated based on the method outlined in the FEH Supplementary Report Number 1[3]. To allow the model to run a time step of 0.5 hours has been selected.

3.3.6 The flows generated by the ReFH spreadsheet are shown in Table 6. The audit sheets generated by the software are attached.

Table 6: Flow calculation results using ReFH

AEP	Flow (m^3/s)
QMED	1.80
20%	2.35
10%	2.80
5%	3.22
2%	3.91
1.33%	4.27
1%	4.55
1%+20%	5.46

[3] Kjeldsen, T.R., (2007), Supplementary Report N. 1, The revitalised FSR/FEH rainfall-runoff method, Centre for Ecology & Hydrology

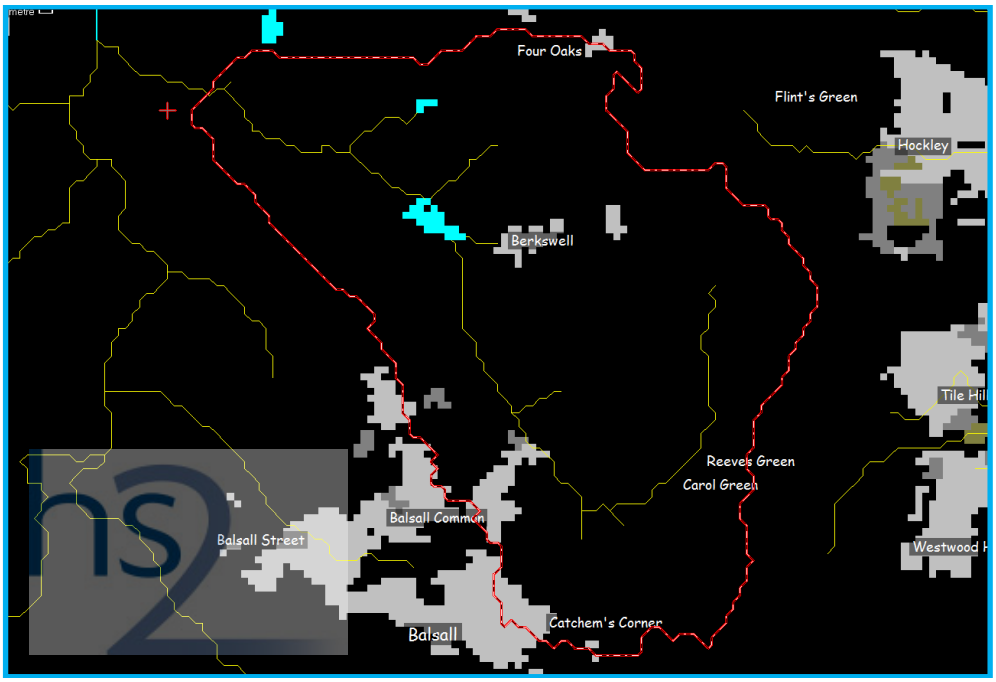
AEP	Flow (m^3/s)
1%+30%	5.90
0.1%	8.10

3.4 Flow estimation point 4 – chainage 152+570 (Bayleys Brook at Marsh Farm viaduct)

3.4.1 The Proposed Scheme will pass over Bayleys Brook approximately 650m upstream of the Bayleys Brook confluence with the River Blythe. This crossing location is referred to as at Marsh Farm viaduct. Therefore, a flow estimation calculation has been undertaken to determine the approximate flow in the Bayleys Brook up to a point located a short distance upstream of the confluence.

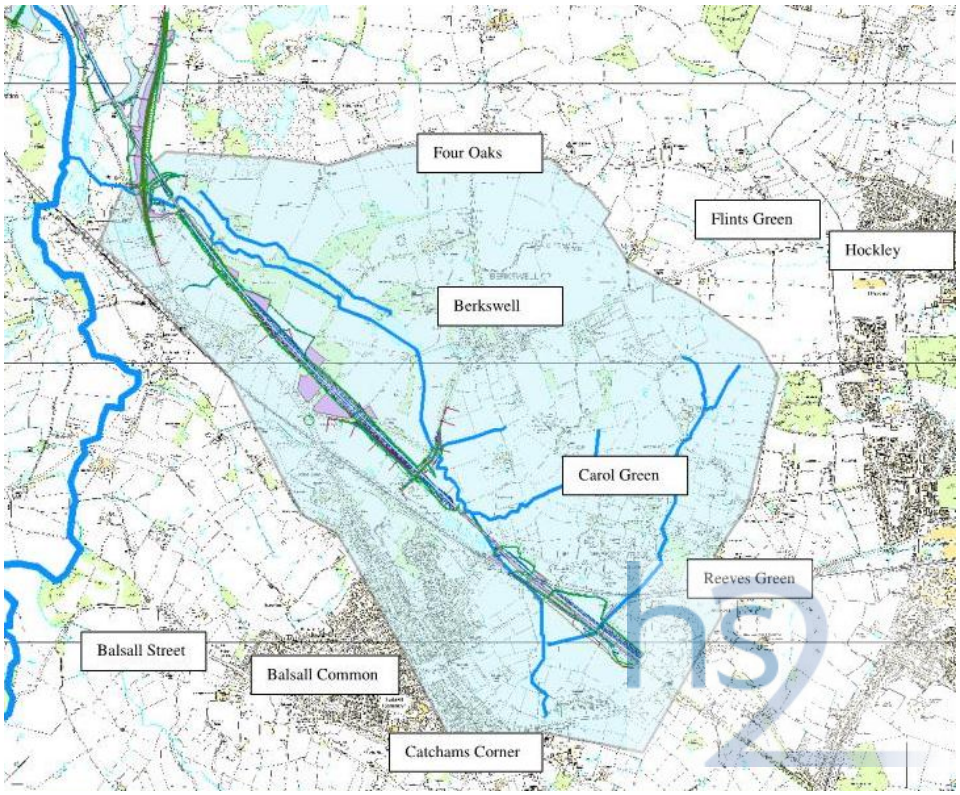
3.4.2 The contributing catchment identified on the FEH CD Rom is shown in Figure 9.

Figure 9: Catchment outline shown on FEH CD Rom



3.4.3 Inconsistencies have been found between the FEH CD Rom and Ordnance Survey mapping sources for sub catchments along the Bayleys Brook. However, at this location the FEH CD Rom is able to represent the catchment size and shape, when compared to Ordnance Survey mapping sources. This is shown in Figure 10.

Figure 10: Catchment outline from Ordnance Survey mapping sources.



3.4.4 The catchment descriptors from the FEH CD Rom have been used without adjustment for this location. These are shown in Table 7.

Table 7: Catchment descriptors from FEH CD Rom

Catchment Descriptors	Value
Area	11.28
SAAR	696
BFIHOST	0.51
SPRHOST	39.4
URBEXT	0.0194
PROPWET	0.3
DPSBAR	26.6
DPLBAR	4.21
c	-0.02631
d1	0.36267
d2	0.3568
d3	0.24937
e	0.30071
f	2.39846

3.4.5 A storm duration of 8.5 hours has been calculated based on the method outlined in the FEH Supplementary Report Number 1. To allow the model to run a time step of 1.7 hours has been selected.

3.4.6 The flows generated by the ReFH spreadsheet are shown in Table 8.

Table 8: Flow calculation results using ReFH

AEP	Flow (m^3/s)
QMED	2.27
20%	2.94
10%	3.46
5%	3.99
2%	4.82
1.33%	5.24
1%	5.56
1%+20%	6.67
1%+30%	7.23
0.1%	9.73

3.4.7 Following a review of this catchment it was deemed appropriate to undertake additional hydrological analysis at this location. Details of the analysis are provided in Annex A.

3.4.8 The flows generated by the FEH statistical method are shown in Table 9.

Table 9: Flow calculation result using FEH statistical method

AEP	Flow (m^3/s)
QMED	1.65
20%	2.35
10%	2.85
5%	2.37
2%	4.13
1.33%	4.51
1%	4.79
1%+20%	5.75
1%+30%	6.23
0.1%	7.57

3.4.9 The flows calculated by the ReFH and FEH statistical methods are similar although the flows estimated using the ReFH are higher. The flows generated using the ReFH method have been taken forward and used in the hydraulic analysis.

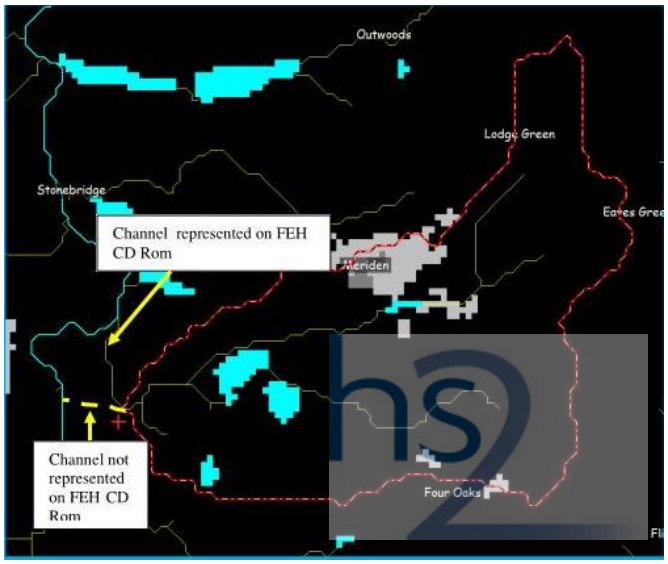
3.4.10 Comparison of the results provided by the two methodologies provides confidence that the calculation method for this study location is both robust and precautionary.

3.5 Flow estimation point 5 – chainage 153+400 (River Blythe Bypass)

3.5.1 The Proposed Scheme will cross a water course at chainage 153+400. This has become referred to as the River Blythe bypass although the channel being crossed is not a bypass channel from the Blythe, therefore the name is misleading.

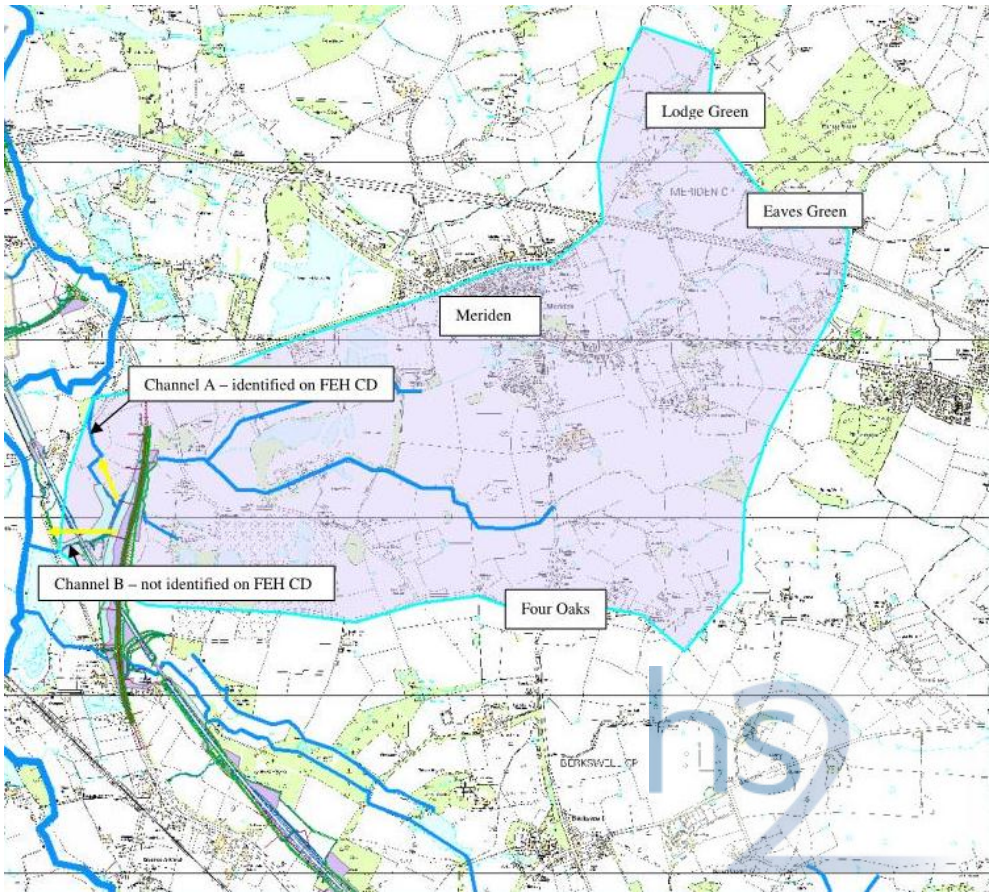
3.5.2 The River Blythe bypass (a tributary of the River Blythe) which will be spanned by the Proposed Scheme is not represented by the FEH CD Rom. It is visible on Ordnance Survey mapping sources. The FEH CD rom data only shows this tributary connecting to the River Blythe by a channel that flows northwards. This channel also exists in reality and is shown on Ordnance Survey mapping sources. Figure 11 indicates the catchment identified by the FEH CD Rom, the location of the channel missing from the FEH CD Rom data and the correctly identified channel.

Figure 11: Catchment outline shown on FEH CD Rom



3.5.3 Ordnance Survey mapping sources have been used to confirm that the configuration of the channel network and that the size and shape of this catchment is representative of this tributary of the River Blythe. This is indicated on Figure 12.

Figure 12: Catchment outline from Ordnance Survey mapping sources



3.5.4 The area and catchment descriptors identified by the FEH CD Rom have been taken forward without any adjustment as these can be confirmed by the Ordnance Survey mapping data. These are shown in Table 10.

Table 10: Catchment descriptors from FEH CD Rom

Catchment descriptors	Value
Area, km^2	7.54
SAAR, mm	695
BFIHOST	0.552
SPRHOST	39.56
URBEXT	0.0252
PROPWET	0.3
DPSBAR, m/km	36.9
DPLBAR, km	3.05
c	-0.0271
d1	0.35816
d2	0.34841
d3	0.27675

Catchment descriptors	Value
e	0.30545
f	2.37586

3.5.5 A storm duration of 6.5 hours has been calculated based on the method outlined in the FEH Supplementary Report Number 1. To allow the model to run a time step of 1.3 hours has been selected.

3.5.6 The flows generated by the ReFH spreadsheet for the whole catchment are shown in Table 11. The audit sheets generated by the software are attached.

Table 11: Flow calculation results using ReFH

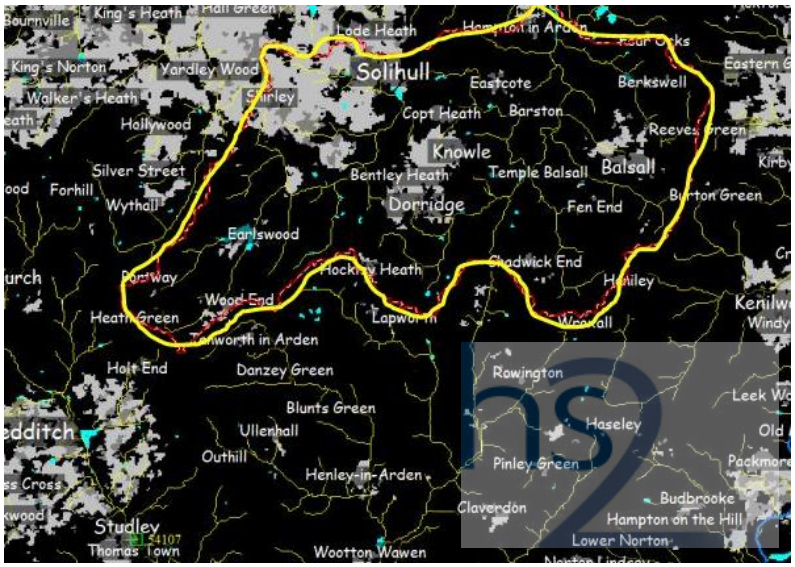
AEP	Flow (m^3/s)
QMED	1.52
20%	1.99
10%	2.36
5%	2.75
2%	3.35
1.33%	3.66
1%	3.90
1%+20%	4.68
1%+30%	5.07
0.1%	7.05

3.5.7 When undertaking river modelling using HEC-RAS, the model will determine the split of flow between Channel A and Channel B as shown on Figure 12.

3.6 Flow estimation point 6 – chainage 154+200 (River Blythe viaduct)

3.6.1 At Chainage 154+200 the Proposed Scheme will cross the River Blythe on the River Blythe viaduct. The catchment of the River Blythe up to this point has been identified using the FEH CD Rom. This is shown in Figure 13.

Figure 13: Catchment outline shown on FEH CD Rom



3.6.2 For assessing the main channel of the River Blythe the catchment outline from the FEH CD Rom, has been taken forward following a review of Ordnance Survey mapping sources to spot any significant anomalies. An independent derived catchment plan has not been produced for the River Blythe at this location. The area and catchment descriptors identified by the FEH CD Rom are shown in Table 12.

Table 12: Catchment descriptors from FEH CD Rom

Catchment Descriptors	Value
Area, km^2	130.69
SAAR, mm	712
BFIHOST	0.405
SPRHOST	39.14
URBEXT	0.082
PROPWET	0.3
DPSBAR, m/km	24.2
DPLBAR, km	15.78
c	-0.02691
d1	0.34715
d2	0.37725
d3	0.27218
e	0.2999
f	2.4121

3.6.3 A storm duration of 17 hours has been calculated based on the method outlined in the FEH Supplementary Report Number 1. To allow the model to run a time step of 1 hour has been selected.

3.6.4 The flows generated by the ReFH spreadsheet are shown in Table 13. The audit sheets generated by the software are attached.

Table 13: Flow calculation results using ReFH

AEP	Flow (m^3/s)
QMED	22.24
20%	28.14
10%	32.62
5%	37.16
2%	44.02
1.33%	47.34
1%	50.06
1%+20%	60.06
1%+30%	65.06
0.1%	82.91

3.6.5 Following a review of this catchment it was deemed appropriate to undertake additional hydrological analysis at this location. Details of the analysis are provided in Annex B of this report.

3.6.6 The flows generated by the FEH statistical method are shown in Table 14.

Table 14: Flow calculation result using FEH statistical method

AEP	Flow (m^3/s)
QMED	20.70
20%	27.70
10%	32.40
5%	37.10
2%	43.80
1.33%	46.90
1%	49.20
1%+20%	59.04
1%+30%	63.96
0.1%	70.60

3.6.7 The flows calculated by the ReFH and FEH statistical methods are similar although the flows estimated using the ReFH are higher. The flows generated using the ReFH method have been taken forward and used in the hydraulic analysis.

3.6.8 Comparison of the results provided by the two methodologies provides confidence that the calculation method for this study location is both robust and precautionary.

3.7 Flow estimation point 7 – chainage 155+075 (Shadow Brook)

3.7.1 The route will cross Shadow Brook at chainage 155+075. The contributing catchment identified on the FEH CD Rom is shown in Figure 14.

Figure 14: Catchment outline shown on FEH CD Rom

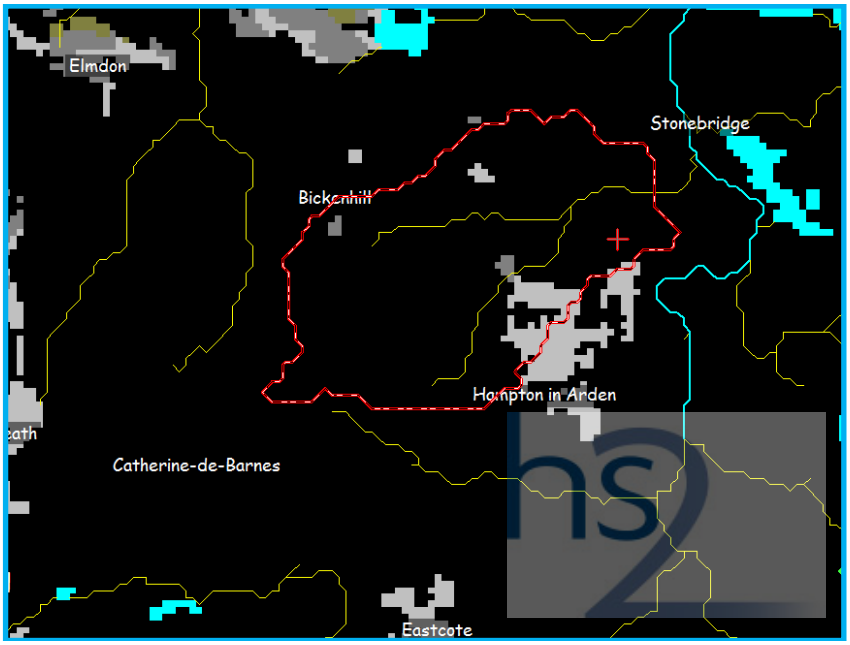
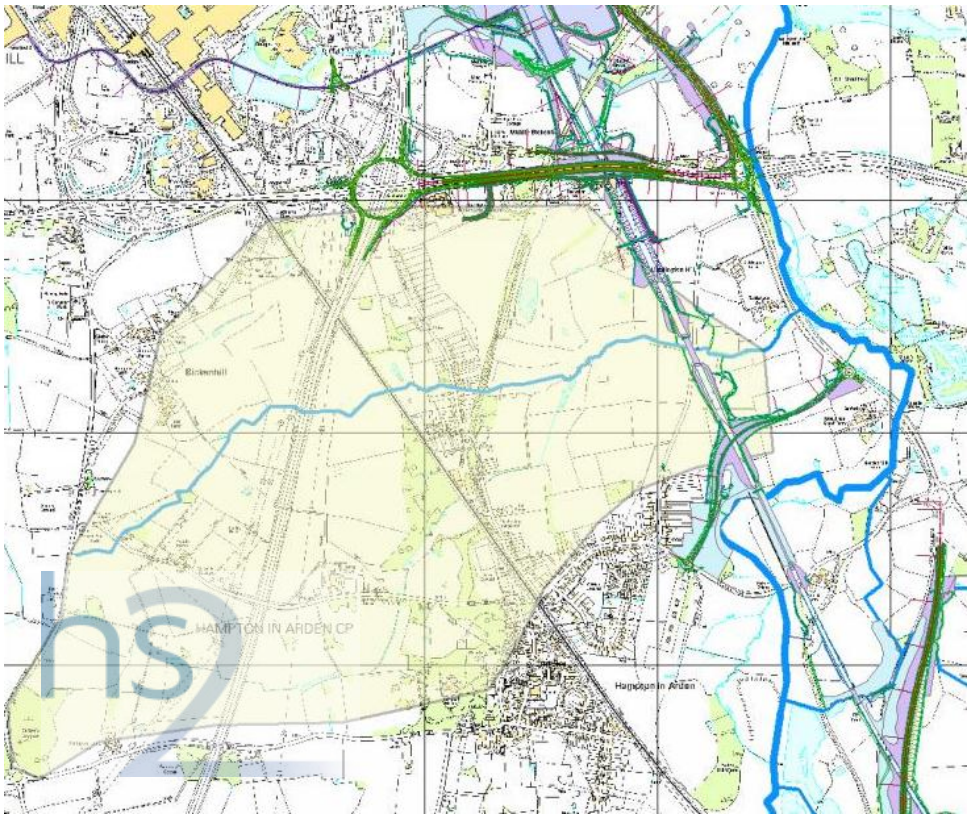


Figure 15: Catchment outline from Ordnance Survey mapping sources



3.7.2 Comparing the catchment defined by the FEH CD Rom and that identified by the Ordnance Survey mapping sources there are differences. However, these are not significant. Therefore, the area and catchment descriptors identified by the FEH CD Rom have been taken forward without any adjustment. These are shown in Table 15.

Table 15: Catchment descriptors from FEH CD Rom

Catchment Descriptors	Value
Area, km^2	4.34
SAAR, mm	686
BFIHOST	0.332
SPRHOST	40.91
URBEXT	0.0288
PROPWET	0.3
DPSBAR, m/km	22.6
DPLBAR, km	1.96
c	-0.02665
d1	0.33828
d2	0.35484
d3	0.30082
e	0.30192
f	2.37825

3.7.3 A storm duration of 5.5 hours has been calculated based on the method outlined in the FEH Supplementary Report Number 1. To allow the model to run a time step of 1.1 hours has been selected.

3.7.4 The flows generated by the ReFH spreadsheet are shown in Table 16.

Table 16: Flow calculation results using ReFH

AEP	Flow (m^3/s)
QMED	1.46
20%	1.93
10%	2.31
5%	2.69
2%	3.29
1.33%	3.59
1%	3.83
1%+20%	4.59
1%+30%	4.98

AEP	Flow (m^3/s)
0.1%	6.86

3.8 Flow estimation point 8 – chainage 156+400 (Hollywell Brook)

3.8.1 The Proposed Scheme will cross Shadow Brook at chainage 156+400 and a road diversion required by the Proposed Scheme will also affect Hollywell Brook. The contributing catchment identified on the FEH CD Rom up to the confluence of the River Blythe is shown in Figure 16. By taking the catchment up to the confluence only one flow calculation is necessary at this preliminary stage.

Figure 16: Catchment outline shown on FEH CD Rom

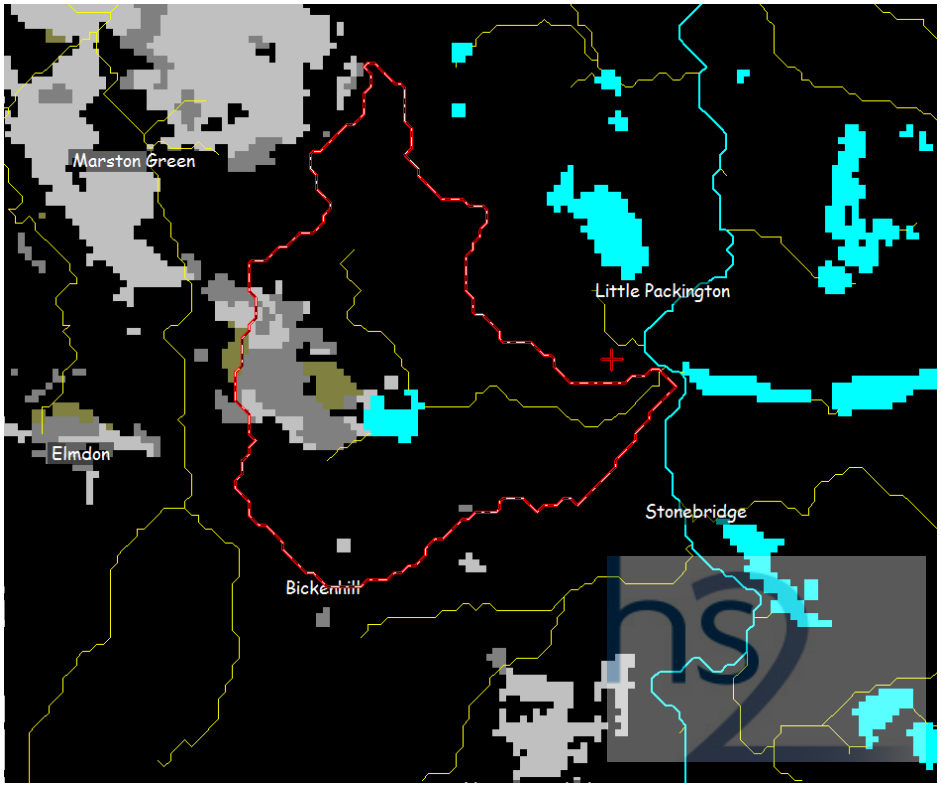
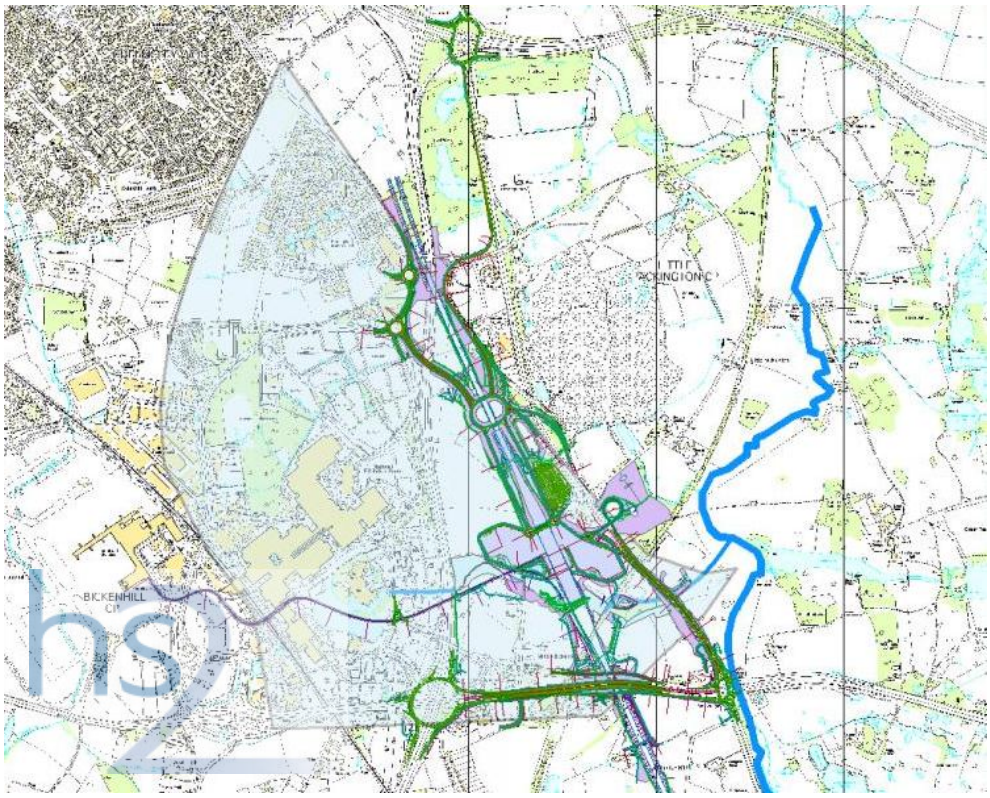


Figure 17: Catchment outline from Ordnance Survey mapping sources



3.8.2 Comparing the catchment defined by the FEH CD Rom and that identified by the Ordnance Survey mapping sources there are clear differences; however, these are not significant. Therefore, the area and catchment descriptors identified by the FEH CD Rom have been taken forward without any adjustment. These are shown in Table 17.

Table 17: Catchment descriptors from FEH CD Rom

Catchment Descriptors	Value
Area, km^2	5.98
SAAR, mm	679
BFIHOST	0.479
SPRHOST	40.49
URBEXT	0.1018
PROPWET	0.31
DPSBAR, m/km	19.6
DPLBAR, km	2.92
c	-0.02671
d1	0.34921
d2	0.32959
d3	0.28999
e	0.30319

Catchment Descriptors	Value
f	2.39176

3.8.3 A storm duration of 5.5 hours has been calculated based on the method outlined in the FEH Supplementary Report Number 1. To allow the model to run a time step of 1.1 hours has been selected.

3.8.4 The flows generated by the ReFH spreadsheet are shown in Table 18. The audit sheets generated by the software are attached.

Table 18: Flow calculation results using ReFH

AEP	Flow (m^3/s)
QMED	1.59
20%	2.10
10%	2.5
5%	2.92
2%	3.55
1.33%	3.88
1%	4.13
1%+20%	4.96
1%+30%	5.37
0.1%	7.40

3.8.5 It should be noted that surface water flows from the National Exhibition Centre (NEC) area that feed the Hollywell Brook are attenuated by Pendigo Lake. This is believed to strictly control all discharges of the Hollywell Brook up to approximately the 2% AEP flood event. However, details of how this lake operates were not available for inclusion in this study. This assessment has been undertaken assuming there is no attenuation within the system and as such is considered a conservative approach.

4 Annex A

4.1 Flow Estimation Point 4 - Chainage 152+570 (Bayleys Brook at Marsh Farm).

4.2 Introduction

4.2.1 This document gives an audit trail of the determination of design flood flows following the Flood Estimation Handbook (FEH) (Institute of Hydrology, 1999) statistical method (Volume 3)[4]. The audit trail assumes familiarity of the reader with the FEH and as such no definitions and explanations of the methodology are given.

4.2.2 Purpose of this more detailed flow estimation exercise is to validate preliminary estimates made using ReFH spreadsheet.

4.2.3 The Versions of FEH software and databases used in this study are given below in Table A1.1.

Table A1.1: Versions of FEH software and databases used in this study

FEH CD-ROM	V 3.0 (2009)
Winfap FEH	V 3.0.003 (2009)
HiFlows UK database	December 2011 release
ReFH	1.1.015

4.3 Site description

4.3.1 The watercourse name, site location and coordinates are given in Table A1.2.

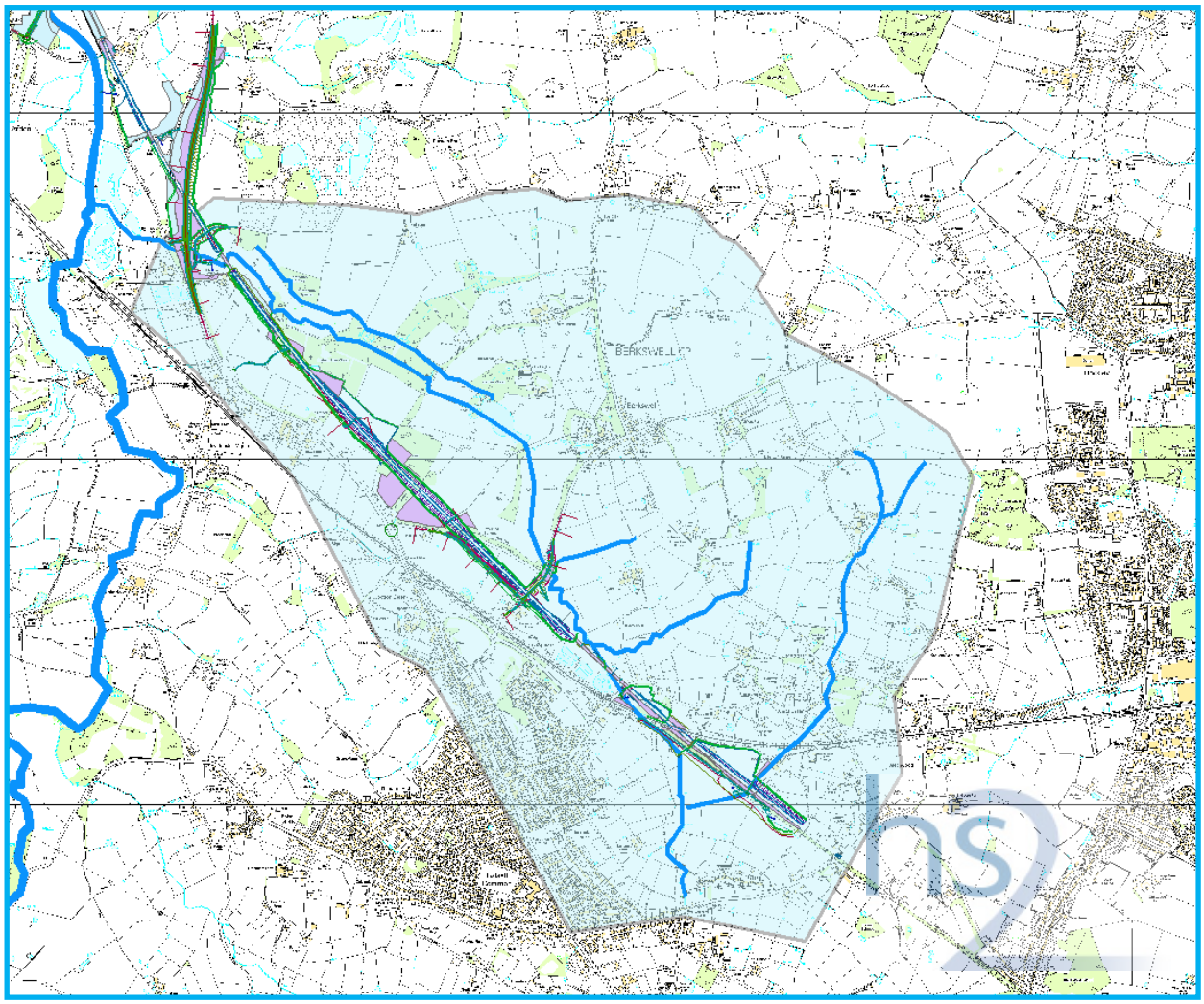
Table A1.2: Watercourse Name and Coordinates

Watercourse:	Bayleys Brook
Site:	HS2 Marsh Farm viaduct
Grid Reference:	422300, 280100
Comments:	

4.3.2 The catchment analysed in this exercise is shown in Figure A1.1.

[4] Flood Estimation Handbook (FEH), (1999) statistical method (Volume 3), Institute of Hydrology

Figure A1.1: Study catchment



4.3.3 Catchment boundary was checked using Ordnance Survey mapping and LiDAR. The catchment descriptor values are given in Table A1.3.

Table A1.3 - Catchment descriptors from FEH CD Rom

AREA (km^2)	11.28
FARL	0.947
FPEXT	0.0728
PROPWET	0.3
BFIHOST	0.51
DPLBAR (km)	4.21
DPSBAR (m/km)	26.6
SAAR (mm)	696
SPRHOST (%)	39.4

URBEXT2000	0.0194

4.3.4 The Ordnance Survey mapping and the FEH CD Rom catchments agreed and so changes were not made to the catchment descriptors.

4.4 Recorded data

4.4.1 Target site is ungauged. The Bayleys Brook flows into the River Blythe. This watercourse is gauged at Whiteacre. However, the catchment area of the River Blythe at this location is 194 km^2. Therefore, the gauge is beyond the acceptable limit for applicability as donor gauge (i.e. catchment area of gauge is larger than five times the size of the study catchment and so comparison not deemed valid).

4.4.2 In addition, the Whitacre gauge is noted as having following limitations of data: considerable upstream storage (attenuation would lead to distortion of flow effects, although probably not an impact for the Qmed); short record: 1985 - 1996; backing up from the Cole and the Tame; gaps in record; urbanisation (6%) above the 2.5% threshold.

4.4.3 On balance therefore, Whitacre gauge should not be used.

4.5 Methodology

4.5.1 The methodologies undertaken as part of this exercise are shown in Table A1.4.

Table A1.4: Methodologies used in food estimation exercise

	Used (Y/N)
FEH Improved Statistical Method (2008)	Y
Revitalised Flood Hydrograph (ReFH) method	Y

4.6 FEH Improved Statistical Method (2008)

4.6.1 QMED has only been estimated based on catchment descriptors this is due to a recognised lack of a suitable observed data, donor and analogues that could be used to make a meaningful improvement to the calculation of QMED.

4.6.2 The QMED from catchment descriptors for this catchment is given in Table A1.5.

Table A1.5: QMED from Catchment Descriptors

		Confidence limits			
	Estimate	**68%**		**95%**	
QMED (m^3/s)	1.65	1.15	2.36	0.8	3.37

4.7 Growth curve estimation

4.7.1 Growth curves have been estimated by defining a pooling group using the FEH WinFAP software. The pooling group has been defined following a detailed review of the hydrologically similar sites selected by the software.

4.8 Pooling group analysis

4.8.1 The pooling group has been created using only stations suitable for QMED and pooling from HiFlows-UK.

4.8.2 The details of the initial pooling group selected by the software is given in Table A1.6

Table A1.6: Details of the Initial Pooling Group

Total number of sites:	18
Total number of years:	500
Short record sites (<8yrs):	1
High discordancy sites:	1
Is subject site gauged?	No
Is subject site included as rank1?	No
Has an 'enhanced single site' analysis been undertaken for a gauged subject site?	No
Range of distance measures:	0.597 – 1.62
Heterogeneity test – H2 value:	5.829
Heterogeneity status:	Strongly heterogeneous
Goodness-of-fit test Acceptable distributions:	GL / GEV / PT3 / other
Action:	Review pooling group

4.8.3 The initial pooling group was reviewed and revised in the ways outline in Table A1.7.

Table A1.7: Revision of pooling group

Station number	**Comment**
33029	Removed due to short record
22003	Very high discordancy. Very high SAAR and very impermeable but natural catchment. Not representative of study catchment so removed
33005	Added on the basis that additional sites needed to increase the years of data available. Except for a poor correlation with the catchment size all other factors are very similar to study site

4.8.4 The details of the final pooling group are given in Table A1.8.

Table A1.8: Details of Final Pooling Group

Heterogeneity test – H2 value:	5.831
Heterogeneity status:	FEH Vol3 Chapter 16.3.2 – "A representative heterogeneous pooling-group gives better flood frequency estimates than either single-site data or a pooling-group that has been made homogeneous by inappropriately removing sites."
Goodness-of-fit test Acceptable distributions:	GL / GEV / PT3 / other

4.8.5 Even after a detailed review of the pooling group it remains strongly heterogeneous. This is a function of the relatively small catchment area which means that the pooling group is made up of diverse catchments. The sites comprising the final pooling group and their characteristics are given in Table A1.9.

Table A1.9: Sites Included in Final Pooling Group

Station	Distance	Years	Qmed AM	L-CV	L Skew	Discordancy
26802 (Gypsey Race @ Kirby Grindalythe)	0.767	10	0.127	0.233	0.25	0.388
25019 (Leven @ Easby)	0.864	31	6.088	0.355	0.396	1.104
27051 (Crimple @ Burn Bridge)	0.957	37	4.514	0.22	0.133	1.362
44006 (Sydling Water @ Sydling st Nicholas)	0.985	35	0.853	0.227	0.087	0.096
44009 (Wey @ Broadwey)	0.997	32	1.688	0.34	0.241	0.329
27010 (Hodge Beck @ Bransdale Weir)	1.255	41	9.42	0.224	0.293	0.417
203046 (Rathmore Burn @ Rathmore Bridge)	1.282	27	10.996	0.126	0.125	1.14
44008 (Sth Winterbourne @ W'bourne Steepleton)	1.305	30	0.413	0.382	0.325	0.98
36009 (Brett @ Cockfield)	1.308	39	3.661	0.26	-0.113	2.089
36010 (Bumpstead Brook @ Broad Green)	1.368	42	6.795	0.428	0.223	1.886
20002 (West Peffer Burn @ Luffness)	1.39	41	3.299	0.292	0.015	0.551
50009 (Lew @ Norley Bridge)	1.465	21	19.025	0.147	-0.249	2.018
45816 (Haddeo @ Upton)	1.483	16	3.539	0.331	0.427	0.656
28033 (Dove @ Hollinsclough)	1.574	30	4.654	0.257	0.403	0.744
25011 (Langdon Beck @ Langdon)	1.617	23	15.362	0.247	0.399	1.619
203049 (Clady @ Clady Bridge)	1.62	27	22.742	0.197	0.123	0.274
33005 (Bedford Ouse @ Thornborough Mill)	4.968	28	21.8	0.178	-0.112	1.346

4.8.6 The growth factors for the range of flows to be assessed in the hydraulic analysis generated by the finalised pooling group are shown in Table A1.10.

Table A1.10: Growth factors generated by final pooling group

AEP	Growth factor
QMED	1.000

AEP	Growth factor
20%	1.426
10%	1.726
5%	2.042
2%	2.505
1.33%	2.731
1%	2.9
0.1%	4.588

4.8.7 Applying the FEH statistical method the following design flood flows have been estimated.

Table A1.11: Flood Estimates generated by FEH Statistical Method

AEP	Final statistical flood flow (m^3/s)
QMED	1.65
20%	2.35
10%	2.85
5%	3.37
2%	4.13
1.33%	4.51
1%	4.79
0.1%	7.57

4.9 Comparison between FEH Statistical Method and ReFH

Table A1.12: Comparison of flows derived using ReFH and FEH Statistical Methods

AEP	ReFH (m^3/s)	FEH Statistical Method (m^3/s)
QMED	2.27	1.65
20%	2.94	2.35
10%	3.46	2.85
5%	3.99	3.37
2%	4.82	4.13
1.33%	5.24	4.51
1%	5.56	4.79
1%+20%	6.67	5.75
1%+30%	7.23	6.23
0.1%	9.73	7.57

4.9.1 Table A1.12 indicates the similarity between the flows derived using the same method. However, the ReFH method derives higher flows across the full range of probability events.

5 Annex B

5.1 Flow Estimation Point 6 - chainage 154+200 (River Blythe viaduct).

5.2 Introduction

5.2.1 This document gives an audit trail of the determination of design flood flows following the Flood Estimation Handbook (FEH) (Institute of Hydrology, 1999) statistical method (Volume 3). The audit trail assumes familiarity of the reader with the FEH and as such no definitions and explanations of the methodology are given.

5.2.2 Purpose of this more detailed flow estimation exercise is to validate preliminary estimates made using ReFH spreadsheet.

5.2.3 The Versions of FEH software and databases used in this study are given below in Table B1.1.

Table B1.1: Versions of FEH software and databases used in this study

FEH CD-ROM	V 3.0 (2009)
Winfap FEH	V 3.0.003 (2009)
HiFlows UK database	December 2011 release
ReFH	1.1.015

5.3 Site description

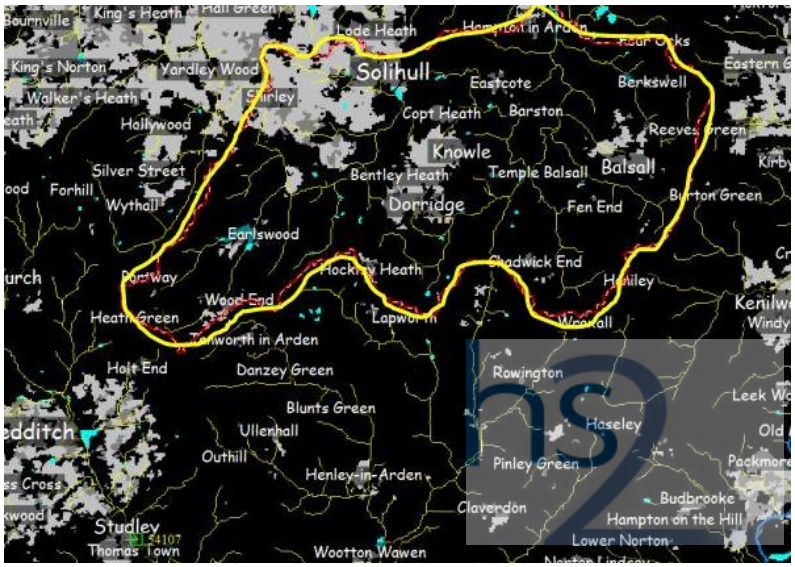
5.3.1 The watercourse name, site location and coordinates are given in Table B1.2.

Table B1.2: Watercourse Name and Coordinates

Watercourse:	River Blythe
Site:	River Blythe viaduct
Grid Reference:	421550, 281750
Comments:	

5.3.2 The catchment analysed in this exercise is shown in Figure B1.1.

Figure B1.1: Study catchment



5.3.3 Catchment boundary was checked using Ordnance Survey mapping and LiDAR. The catchment descriptor values are given in Table B1.3.

Table B1.3 - Catchment Descriptors from FEH CD Rom

AREA (km^2)	130.69
FARL	0.949
FPEXT	0.1152
PROPWET	0.29
BFIHOST	0.405
DPLBAR (km)	15.78
DPSBAR (m/km)	24.2
SAAR (mm)	712
SPRHOST (%)	39.14
URBEXT2000	0.082

5.3.4 The Ordnance Survey mapping and the FEH CD Rom catchments agreed and so changes were not made to the catchment descriptors.

5.4 Recorded data

5.4.1 The catchment area of the River Blythe at Whiteacre is 194km^2 compared to the catchment area at the River Blythe viaduct which is 131km^2. The difference in catchment area is less than a factor of 5 different indicating that the recorded data at White acre may be of relevance enabling the use of the gauging station as a donor site to flow estimation. However, the gauge at Whitacre gauge is noted as having the following limitations of data:

- considerable upstream storage (attenuation would lead to distortion of flow effects, although probably not an impact for the Qmed);

- short record: 1985 - 1996;
- backing up from the River Cole and the River Tame;
- gaps in record; and
- urbanisation (6%) above the 2.5% recommended threshold.

5.4.2 Therefore, the data at the Whitacre gauge has not been employed as it is possible it will introduce additional errors to the estimation process

5.5 Methodology

5.5.1 The methodologies undertaken as part of this exercise are shown in Table B1.4.

Table B1.4: Methodologies used in flood estimation exercise

	Used (Y/N)
FEH Improved Statistical Method (2008)	Y
Revitalised Flood Hydrograph (ReFH) method	Y

5.6 FEH Improved Statistical Method (2008)

5.6.1 QMED has only been estimated based on catchment descriptors this is due to a recognised lack of a suitable observed data, donor and analogues that could be used to make a meaningful improvement to the calculation of QMED.

5.6.2 The QMED from catchment descriptors for this catchment is given in Table B1.5.

Table B1.5: QMED from catchment descriptors

		Confidence limits			
	Estimate	**68%**		**95%**	
QMED (m^3/s)	20.73	14.49	29.66	10.12	42.45

5.7 Growth curve estimation

5.7.1 Growth curves have been estimated by defining a pooling group using the FEH WinFAP software. The pooling group has been defined following a detailed review of the hydrologically similar sites selected by the software.

5.8 Pooling group analysis

5.8.1 The pooling group has been created using only stations suitable for QMED and pooling from HiFlows-UK.

5.8.2 The details of the initial pooling group selected by the software is given in Table B1.6.

Table B1.6: Details of the Initial Pooling Group

Total number of sites:	13
Total number of years:	523
Short record sites (<8yrs):	0
High discordancy sites:	0
Is subject site gauged?	No
Is subject site included as rank1?	No
Has an 'enhanced single site' analysis been undertaken for a gauged subject site?	No
Range of distance measures:	0.308 – 604
Heterogeneity test – H2 value:	6.136
Heterogeneity status:	Strongly heterogeneous
Goodness-of-fit test Acceptable distributions:	GL / GEV / PT3 / other
Action:	Review pooling group

5.8.3 The initial pooling group and each station included in the group were reviewed in detail. None of the stations indicated reasons for their exclusion from the pooling group for hydrological reasons other than distance from the study site. Therefore it was felt beneficial to retain all sites rather than exclude sites for reasons of distance only.

5.8.4 The sites comprising the final pooling group and their characteristics are given in Table B1.7.

Table A1.9: Sites included in final pooling group

Station	**Distance**	**Years of data**	**Qmed AM**	**L-CV**	**L Skew**	**Discordancy**
54040 (Meese @ Tibberton)	0.308	36	4.83	0.225	0.336	1.95
33007 (Nar @ Marham)	0.314	27	3.665	0.224	0.011	0.497
68020 (Gowy @ Bridge Trafford)	0.489	30	15.156	0.143	-0.15	1.362
39025 (Enborne @ Brimpton)	0.532	42	16.9	0.203	0.138	1.413
35008 (Gipping @ Stowmarket)	0.534	43	12.624	0.302	0.111	0.595
33011 (Little Ouse @ County Bridge Euston)	0.535	48	3.855	0.317	0.03	1.164
54041 (Tern @ Eaton on Tern)	0.552	37	11.332	0.204	0.125	0.409
15008 (Dean Water @ Cookston)	0.563	53	26.832	0.132	0.059	1.23
33057 (Ouzel @ Leighton Buzzard)	0.583	28	7.575	0.167	-0.107	0.957
52010 (Brue @ Lovington)	0.616	45	36.285	0.279	0.37	0.916
25005 (Leven @ Leven Bridge)	0.63	48	43.54	0.241	0.269	0.435
37014 (Roding @ High Ongar)	0.636	46	10.678	0.255	-0.142	1.368

53013 (Marden @ Stanley)	0.64	40	15.377	0.313	0.263	0.702

5.8.5 The growth factors for the range of flows to be assessed in the hydraulic analysis generated by the finalised pooling group are shown in Table B1.10

Table B1.10: Growth factors generated by final pooling group

AEP	Growth factor
QMED	1.000
20%	1.338
10%	1.564
5%	1.792
2%	2.111
1.33%	2.262
1%	2.373
0.1%	3.405

5.8.6 Applying the FEH statistical method the following design flood flows have been estimated.

Table B1.11: Flood Estimates generated by FEH Statistical Method

AEP	Final statistical flood flow (m^3/s)
QMED	20.7
20%	27.7
10%	32.4
5%	37.1
2%	43.8
1.33%	46.9
1%	49.2
0.1%	70.6

5.9 Comparison between FEH Statistical Method and ReFH

5.9.1 Table A1.12 indicates the similarity between the flows derived using the same method. However, the ReFH method derives higher flows across the full range of probability events.

Table A1.12: Comparison of flows derived using ReFH and FEH Statistical Methods

AEP	**ReFH (m^3/s)**	**FEH Statistical Method (m^3/s)**
QMED	22.24	20.70
20%	28.14	27.70
10%	32.62	32.40
5%	37.16	37.10
2%	44.02	43.80
1.33%	47.34	46.90
1%	50.06	49.20
1%+20%	60.06	59.00
1%+30%	65.06	63.96
0.1%	82.91	70.6